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Short communication

Medial gastrocnemius is more activated than lateral gastrocnemius in sural nerve induced reflexes during human gait

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Abstract

In humans the sural nerve was stimulated at one of 16 phases of the step cycle. In MG (medial gastrocnemius) the amplitude of the P2 responses (latency 80–93 ms) was on average 1.3 times larger than the corresponding background activity while this was 0.9 for LG (lateral gastrocnemius; predominantly suppressive responses). It is speculated that such differences contribute to an exorotation moment during gait.

Keywords: Human gait; Sural nerve; Reflex gain; Exteroceptive reflex; Medial gastrocnemius; Lateral gastrocnemius; Biceps femoris

In the cat, facilitatory responses following sural nerve stimulation are larger in MG than in LG both at rest [2,10] and during treadmill locomotion [1]. In humans, sural nerve evoked responses exist in MG during gait [6] but they are relatively small and it is not known whether they are larger than those in LG. Also unknown is how they relate to responses in muscles such as BF (biceps femoris) which are strongly activated in this type of reflex responses [6,14].

In five adult subjects, the EMG activity was recorded by means of surface electrodes over MG, LG and BF, as described elsewhere [6]. Force plates were used to determine footfall. Stimulating electrodes were positioned at the ankle of the left leg over the sural nerve. The stimulation consisted of a train of five rectangular pulses of 1 ms, given over a period of 21 ms. During the experimental runs, stimuli at 2 times perception threshold ($2 \times$ PT) were given. The step cycle was divided in 16 phases of equal length of time. Stimuli were given at one of these phases. At least ten responses for each type of stimulus condition were sampled. Control trials were taken at exactly the same intervals in the step cycle as used for the stimulus trials. All trials (stimulus and control) were randomly mixed and separated by random interval of 3–5 s. Each subject was tested in several experiments on a split-belt treadmill to examine the stability of the observed responses under a variety of dynamic conditions. Subjects walked or ran either with the left and right belts moving at the same speed or at different speeds (one side 2 or 4 times faster than the other side, see [3]). In total, 24 experiments were performed. With few exceptions, stimulus conditions were sufficiently constant within each experiment (as controlled by measuring the current; see [7]).

Off-line, the signals were averaged ($n = 10$) for all stimuli belonging to the same phase. In suppressive responses the reflex activity was below the background EMG level normally present at that particular time of the step cycle. To be able to show such responses the controls were subtracted from the corresponding reflex data to obtain the 'pure' reflex responses, independent from the background EMG activations.

To quantify the magnitude of the reflex responses, the mean amplitude was calculated within a time window [6].

An example of subtracted P2 responses in MG and LG is shown in Fig. 1 for stimulation in 16 different phases of the step cycle.

In MG it can be seen that a facilitatory response (black areas between vertical lines in Fig. 1 left) occurs in most of the traces where MG showed background activation noise. These responses, known as P2 responses [6], occurred in all subjects with a mean latency of 82 ms and a mean duration of 30 ms. In contrast to MG a similar facilitatory P2 response (in casu between 83 and 113 ms) was rarely present in LG, although LG is mostly a syner-

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gist of MG. In fact, the responses within the identical P2 window, used to highlight the P2 responses in MG, were suppressive in the simultaneously recorded LG (Fig. 1 right). The results of a second subject are shown in Fig. 2A.

In confirmation of previous studies on humans [4], it was found that in MG the facilitatory P2 responses to sural nerve stimulation were most prominent in early and middle stance (phases 12–15) but were sometimes absent in late stance (phases 16, 1 and 2), despite the presence of background activity. In LG, the same stimulation induced suppressive P2 responses in the middle of the stance phase (phases 15 and 16).

From Figs. 1 and 2 it is clear that the responses were not large but they were reproducible throughout most of the step cycle. For the latter reason a method (the reflex/background ratio method [6]) could be used which summarizes the strength of the responses in any given experiment throughout the step cycle, irrespective of the phases in which the responses appear.

A reflex/background ratio was calculated by adding all the measurements of the raw P2 reflex responses at the 16 phases and dividing this sum by the sum of all the 16 corresponding controls. A value above 1 indicates the predominant presence of facilitatory reflexes while a ratio below 1 is consistent with a majority of suppressive reflexes.

The ratios of MG and LG were compared to those of biceps femoris (BF). As expected from previous studies [6], in BF the ratios were always positive (mean 2.38; S.D. 1.53). In general the MG ratios were also above 1 but they were considerably smaller than those of BF (mean 1.28; S.D. 0.27). In MG suppressive ratios were found in only one subject, while for LG a ratio below 1 appeared in all subjects. Out of a total of 24 experiments on five subjects there was only one experiment in which the P2 response ratio was smaller for MG than for LG. For each subject, the changes in locomotor condition had no clear effect.

In conclusion, the MG and LG responses in humans show the same differential reflex activation as observed in the cat [1,10]. Facilitatory responses dominated in MG while suppressive responses prevailed in LG. For postural perturbations a similar result was obtained [12]. Medium latency P2-like facilitatory responses were larger in MG than LG. In contrast, such clear difference was not found in sural nerve induced reflexes in a study using sitting humans and single unit recordings, although larger suppressive responses were seen in LG as compared to MG [9].

The functional role of the difference in MG and LG contribution in sural nerve reflexes has only recently been discussed in terms of movements outside the sagittal plane [13]. In humans, MG can be activated separately from LG, for example during exorotation and lateral leg raising [11]. Evidence for a role of sural nerve reflexes in exorotation [8] comes from our earlier finding that sural nerve stimulation during running induces clearly more facilitatory responses in BF than in ST (semitendinosus) [5,14]. The presently described MG/LG difference further supports the idea of exorotation. It is speculated that during the

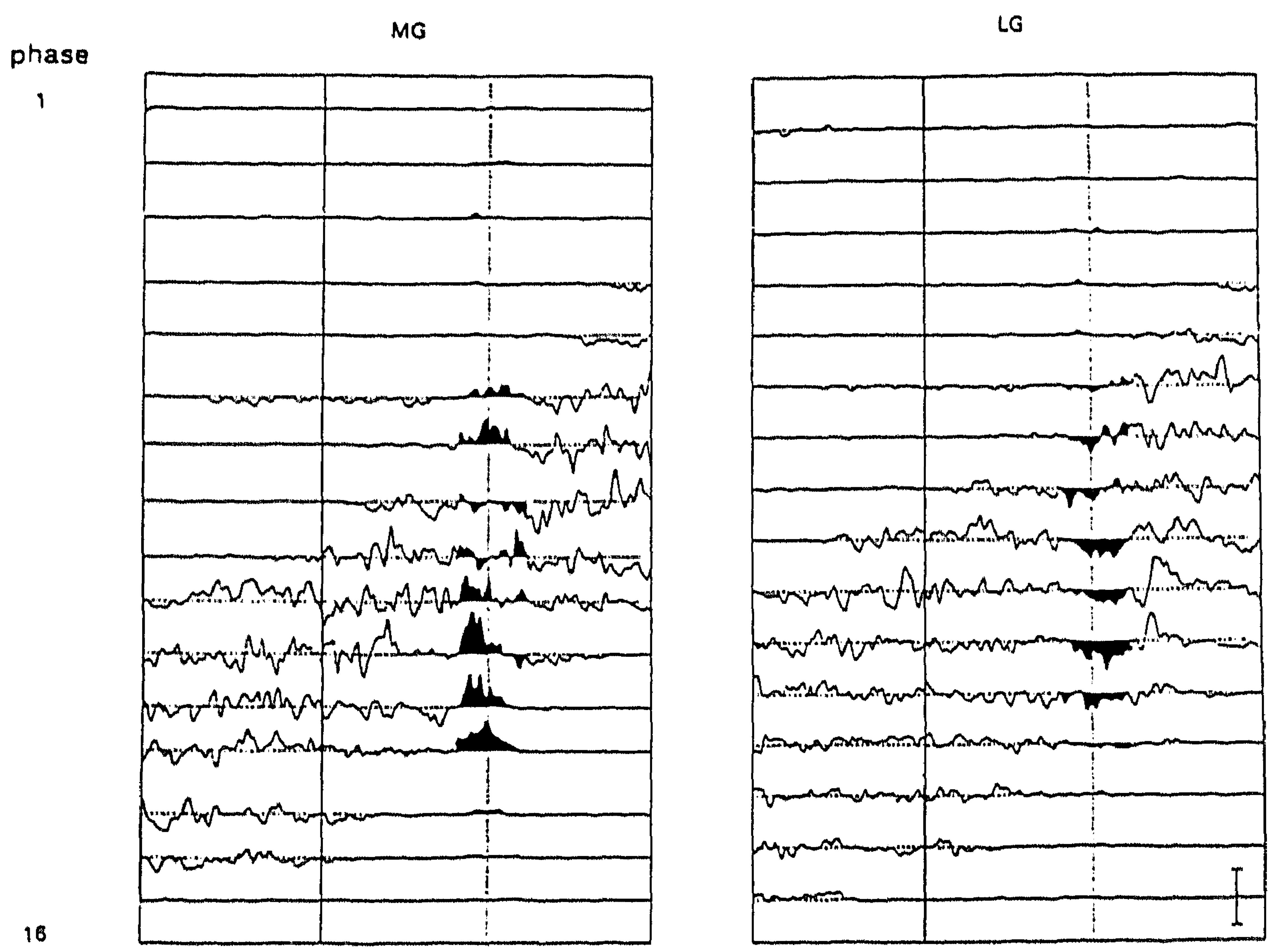

Fig. 1. Averaged ($N = 10$) responses in MG and LG to $2 \times$ PT sural nerve stimulation at 16 different phases of the step cycle in one subject. Phase 1 corresponds with the onset of the contralateral stance. The traces show P2 subtracted reflex responses indicated by black areas (reflex responses minus background activity) during running at 6 km/h. Cal.: 100 ms (time between vertical lines), Y-scale: 1 mV (EMG).

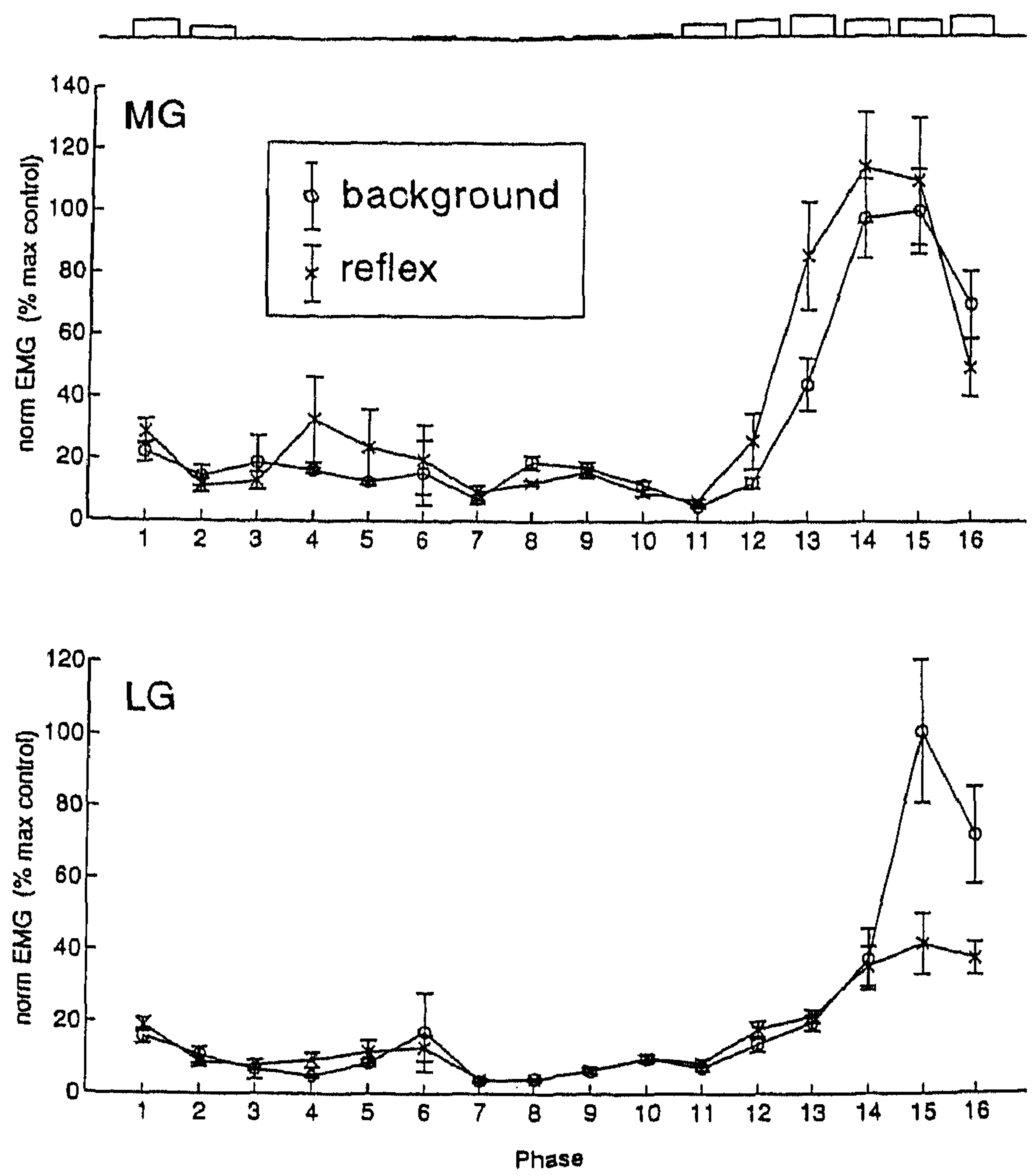

Fig. 2. Comparison of amplitude of averaged P2 responses in MG and LG of one subject following sural nerve stimulation at 2×PT. Top: the samples taken from the force-plate in the treadmill allows one to determine in which phases the foot was on the belt. Phase 11 corresponds to touchdown of the limb in which the sural nerve was stimulated. Bottom: data on reflexes and background activity were normalized with respect to the maximum background activity as observed in the control activity periods of the corresponding muscles. Data from split-belt walking with 6 km/h on the ipsilateral stimulated side and 1.5 km/h on the contralateral side.

stance phase of gait, when the foot is on the ground, the skin on the lateral side of the foot is stretched because of the rotation of the body (caused by the contralateral inward swinging leg). The presently descibed toe-out moment caused by sural nerve activity could help in resisting this passive rotation.

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